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Original Article

Pharyngeal airway space changes in Thai Mandibular setback patients

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Abstract

Background/Objective: The aims of this study were to determine the mean pharyngeal airway space (PAS) area before and after mandibular setback surgery with Bilateral Sagittal Split Ramus Osteotomy (BSSRO) in class III skeletal deformity patients and to identify the correlation between the amount of mandibular setback and PAS change.

Materials and Methods: Thirty-two patients who had undergone mandibular setback surgery with BSSRO at the Department of Oral Surgery, Faculty of Dentistry, Chulalongkorn University (Bangkok, Thailand) from January 2010-December 2015 were included in this study. The PAS areas were measured from lateral cephalometric radiographs preoperatively (T0), immediately postoperatively (TPO), 6 months follow-up (T6), and 1 year follow-up (T12). The setback amount and change in PAS area were calculated and the correlation between them analyzed.

Results: The mean setback was 6.19 ± 0.54 mm. The mean PAS area was 471.54 ± 30.31 mm^2 at T0, 444.39 ± 31.29 mm^2 at TPO, 415.77 ± 25.67 mm^2 at T6, and 406.1 ± 22.76 mm^2 at T12. The mean PAS area change was 27.14 ± 20 mm^2 at TPO, 55.76 ± 22.11 mm^2 at T6, and 65.41 ± 21.35 mm^2 at T12 compared with the PAS area at T0. A positive correlation between the amount of setback and the reduction in PAS area was found at T6 ($p < 0.05$).

Conclusions: There was a significant correlation between the amount of setback and the reduction of PAS area at T6. Moreover, the PAS area was decreased after one-year follow-up.

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Keywords: Class III Skeletal deformity; Lateral cephalometric; Mandibular setback surgery; Obstructive sleep apnea; Pharyngeal airway space

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Introduction

Class III skeletal deformity is a condition associated with mandibular protrusion, maxillary retrusion or both (Obwegeser, 1969, Legan et al., 1981, Samman et al., 1992). This condition can be corrected by orthodontic treatment combined with orthognathic surgery (Wenzel et al., 1989), i.e. mandibular setback surgery by Bilateral Sagittal Split Ramus Osteotomy (BSSRO). However, the tongue and hyoid bone are connected to the mandible via the genioglossus, geniohyoid, and mylohyoid muscles. Moving the mandible backwards results in a downward and posterior movement of the hyoid bone, and posterior movement of the tongue, and these shifts decrease the pharyngeal airway space (PAS) (Enacar et al., 1994).

Obstructive sleep apnea (OSA) patients experience repeated collapse of the pharyngeal airway during sleep leading to airflow limitation, oxygen desaturation, and sleep fragmentation and are at risk for developing coronary disease, arrhythmias, stroke, and heart failure (Lye, 2008, Canellas et al., 2016). Anatomically, individuals with OSA are characterized by mandibular deficiency, inferior hyoid position, and limited PAS (Riley et al., 1983, Battagel and L'Estrange, 1996). Thus, BSSRO may reproduce the anatomic relationships seen in OSA, and OSA has been reported to develop in some of these patients (Guilleminault et al., 1985, Riley et al., 1987). Because PAS reduction is an important factor in developing OSA and may cause death, it must be considered before surgical treatment planning. Therefore, it is critical to determine the amount of PAS reduction associated with BSSRO.

Many studies have evaluated the effect of BSSRO on the PAS; however, the results have been inconsistent. Previous studies demonstrated that after surgery, the PAS could be categorized into two groups, with (Riley et al., 1987, Greco et al., 1990, Hochban et al., 1996, Tselnik and Pogrel, 2000, Eggensperger et al., 2005, Cho et al., 2015) or without changes in PAS (Takagi et al., 1967, Athanasiou et al., 1991, Kawakami et al., 2005, Pereira-Filho et al., 2011). Other studies reported a relationship between the amount of setback and PAS reduction after surgery (Hochban et al., 1996, Tselnik and Pogrel, 2000, Cho et al., 2015). One study found no relationship between the PAS change, the position of the hyoid bone, and the amount of setback after surgery (On et al., 2015). In contrast, Hochban et al. showed that there was a slight relationship between the amount of setback and soft tissue change in PAS (Hochban et al., 1996). Other studies found a relationship between the mean setback amount and PAS reduction at different reference points (Eggensperger et al., 2005, Cho et al., 2015).

Race is another factor that affects anatomical structures, facial, and respiratory dimensions. Lew et al. found that Mongoloids and Caucasians have different standard facial soft tissue parameters (Lew et al., 1990). Bunsha found that the upper airway dimensions in each race are slightly different (Bunsha, 2011). Indeed, the incidence of Class III skeletal deformity requiring surgical correction is 15.8% in Southeast Asians (Watkinson et al., 2013), however, there has been no study concerning the relationship between the amount of setback and the change in PAS area after mandibular setback surgery in Thai people.

Previous studies evaluated PAS size in distance and area by analyzing lateral cephalometric radiographs using reference points in the maxillofacial region (Tselnik and Pogrel, 2000, Guven and Saracoglu, 2005, Chen et al., 2007, Cho et al., 2015). The advantages of using lateral cephalograms include their common use, simplicity, low cost, and the results are easily compared with other studies. Therefore, the aim of our study was to identify the mean PAS area on lateral cephalometric radiographs and to determine the correlation between the amount of mandibular setback and the change in PAS before and after mandibular setback surgery with BSSRO in Thai patients with class III skeletal deformity.

Materials and methods

This retrospective study was approved by the Ethics and Research Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2016-041) The required sample size was determined using The PS: Power and Sample Size Calculation Software, Version 3.0.4. (Vanderbiilt University, Nashville, TN) and previously published results (Guven and Saracoglu, 2005) that indicated that the required sample size was 10 patients. We analyzed the lateral cephalometric radiographs of thirty-two patients (11 males, 21 females) with class III skeletal deformity who had undergone mandibular setback surgery with BSSRO at the Department of Oral Surgery, Faculty of Dentistry, Chulalongkorn University (Bangkok, Thailand) from January 2010-December 2015, aged 18-51 years (mean age 25.16 years). Patients who had undergone oral and maxillofacial surgery, tonsillectomy, adenoidectomy, or genioplasty, had a history of or currently had obstructive sleep apnea (OSA) or congenital abnormalities that could affect changes in the PAS were excluded.

The lateral cephalometric radiographs were taken when the patient was upright and patient's neck was in the erect position and the Frankfort plane was aligned horizontally using a Kodak 9000C Extra-oral imaging system and were collected using the INFINITT program version 3.0.7.1 in the Department of Radiology, Faculty of Dentistry, Chulalongkorn University. The PAS areas were measured by cephalometric analysis at preoperatively (T0), immediately postoperatively (TPO), 6 months follow-up (T6), and 1 year follow-up (T12).

Cephalometric analysis

The PAS area was measured from lateral cephalograms using the Adobe Photoshop CS4 extended version. The measurements were performed by three investigators who had been trained by an experienced radiologist (PS). Eight cephalometric radiographs were randomly selected and the PAS value was measured again 1 month after the initial measurement. The intraclass correlation coefficient test was used to analyze the intra-observer reliability. The intraclass correlation coefficients for each examiner ranged from 0.996- 1. The radiographs were traced by the observer who had the highest average coefficient (0.99875) to minimize measurement error. The lateral cephalograms were calibrated using a measurement unit on a nasion pointer in centimeters. The PAS area evaluated in this study consisted of an anterior border defined as the line along the posterior of the tongue, a posterior border defined as the posterior pharyngeal wall, a D1 line drawn across P point (the lowest point of the soft palate) parallel to the palatal plane defined the superior border, and a D2 line drawn across V point (the junction between the epiglottis and the base of the tongue) parallel to the palatal plane defined the inferior border (Figure 1). The PAS areas before surgery were defined as T0, and the PAS areas at immediate postoperative, 6 months follow-up, and 1-year follow-up were defined as TPO, T6, and T12, respectively.

The pre-and post-surgical radiographs were superimposed to analyze the amount of mandibular setback defined as the distance between the L1 line (the line perpendicular to the palatal plane through the Pog point) and the L2 line (the line perpendicular to the palatal plane through the Pog' point) using the palatal plane as the reference plane (Figure 2).

Statistical analysis

The amount of setback and PAS area at each time are presented as mean and standard deviation (SD) before and after surgery. The relationship between the amount of setback and change in PAS area for each patient at each time point were analyzed by Pearson's correlation, with $p < 0.05$ determined to be significant. The SPSS statistical software V.17.0 was used to analyze all results. The intraclass correlation coefficient test was used to assess intra-observer variation.

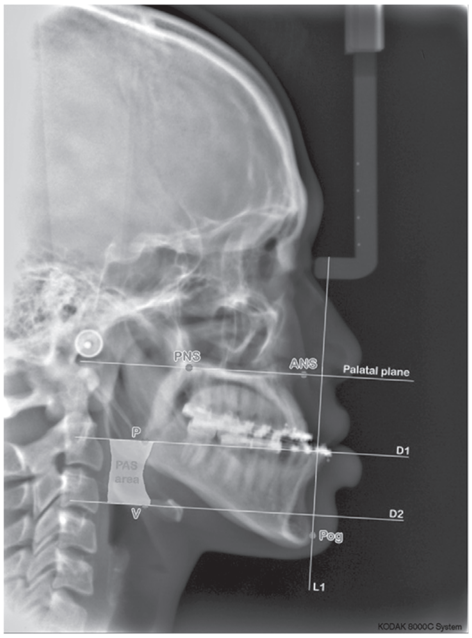

Figure 1: Parameters and cephalometric landmarks. Palatal plane; the distance between ANS and PNS, **PNS** (Posterior nasal spine); the posterior point of hard palate, **ANS** (Anterior nasal spine); the anterior point of hard palate, **P**; lowest point of soft palate, **V** (Vallecula); the junction between epiglottis and base of tongue, **L1 line**; the line perpendicular to palatal plane through Pog point,

The PAS area (yellow area) was defined by an anterior border; the line along the posterior of tongue, posterior border; the posterior pharyngeal wall, superior border; **D1 line** draws across P point parallel to palatal plane, and inferior border; **D2 line** draws across V point parallel to palatal plane.

Figure 2: Representative superimposed pre- and post-surgical radiograph used to determine the amount of mandibular setback in distance (Pog-Pog'). (**Pog** (Pogonion); the most anterior point of mandible at symphysis, **Pog'**; Pogonion point after mandibular setback at T1, T2 and T3. **L2 line**; the line perpendicular to the palatal plane through Pog' point.

Results

The mean amount of mandibular setback was 6.19 ± 0.54 mm (Table 1). The mean PAS area was 471.54 ± 30.31 mm^2 at T0 (Table 2). Mandibular setback surgery resulted in a decrease in PAS area that steadily decreased over time to 406.1 ± 22.76 mm^2 at T12.

The measurements of the PAS area before and after surgery showed a reduction of 27.14 ± 20 mm^2 from T0-TPO and this amount increased to 65.41 ± 21.35 mm^2 from T0-T12 (Table 2).

The correlation between the amount of setback and the reduction in PAS area was significant only at T2 ($p < 0.05$) (Table 3).

Table 1: Mean setback amount.

	N	Mean setback amount (mm)	Standard deviation
Female	21	6.13	0.62
Male	11	6.29	1.05
All	32	6.19	0.54

min = 1.6 mm and max = 10.6 mm

Table 2: Mean PAS area at different times and the PAS area change after surgery.

	PAS area (mm2)				PAS area change					
	T0	TPO	T6	T12	T0-TPO		T0-T6		T0-T12	
					mm^2	%*	mm^2	%*	mm^2	%*
Mean	471.54	444.39	415.77	406.10	27.14	5.76	55.76	11.83	65.41	13.87
SD	30.31	31.29	25.67	22.76	20.00		22.11		21.35	
Min	212.7	160.3	158.2	186.1	7.6		1.3		3.1	
Max	811.5	819.6	750.4	685.3	251.4		357		398.7	

T0: preoperative, TPO: immediate postoperative, T6: 6 months follow-up and T12: 1 year follow-up, T0-TPO: The PAS area change between immediate postoperative and preoperative, T0-T6: The PAS area change between 6 months follow-up and preoperative, and T0-T12: The PAS area change between 1 year and preoperative

%* = Percent PAS area reduction

Table 3: Correlation between the amount of setback and the reduction in PAS area.

		T0-TPO	T0-T6	T0-T12
Setback	Pearson Correlation	.175	.362*	.186
	Sig. (2-tailed)	.338	.042	.307
	N	32	32	32

*Indicates a significant correlation ($p < 0.05$ level (2-tailed)).

Discussion

Mandibular setback surgery, BSSRO, results in a reduction in the PAS, which has been implicated in the development of OSA in patients post-operatively. The present study retrospectively evaluated the amount of PAS reduction after BSSRO in Thai patients. We found that the PAS, measured by area, was reduced after mandibular setback surgery and gradually decreased over time. There was a significant correlation between the amount of mandibular setback and the reduced PAS area at T6 after mandibular setback surgery. However, there was likely no correlation at TPO, because maxillo-mandibular fixation was not used in every case when the radiographs were taken depending on the post-operative occlusion stability and at 1 year postoperative (T12) due to soft tissue adaptation to compensate for the decreased pharyngeal airway. In addition, adaptive postural changes may have occurred that also may account for the lack of correlation at T12. Muto et al. reported that a 10° increase in cervical inclination resulted in a 4 mm increase in the PAS (Muto et al., 2008). Similar to our results, Hasabe et al. (Hasebe et al., 2011) found no correlation, while several others did (Liukkonen et al., 2002, Muto et al., 2008, Cho et al., 2015). These disparate findings may be due to differences in the evaluated times and anatomic areas.

Our results are in line with those of previous studies evaluating changes in PAS using lateral cephalograms. Tselnik and Pogrel measured PAS distance and PAS area using lateral cephalograms in 14 adults and found that a mean setback of 9.04 ± 4.92 mm resulted in a 12.8% reduction in PAS area (Tselnik and Pogrel, 2000) They also found a strong correlation between the amount of mandibular setback and reduced PAS area at long-term follow-up. Guven and Saracoglu studied the PAS on 15 lateral cephalograms measured in area and also found significant pharyngeal airway narrowing, however, there was no significant correlation between the amount of mandibular setback and the change in PAS area in early and long-term postoperative periods (Guven and Saracoglu, 2005). In addition, other studies reporting mean setback amounts ranging from 5.6-7.5 mm, similar to the setback amount in our study, reported decreases in PAS distance ranging from 2.0-4.4 mm (Kawakami et al., 2005, Marsan et al., 2009, Abdelrahman et al., 2011, Cho et al., 2015).

Race or ethnicity affects craniofacial parameters. Considering other studies with similar setback amounts, our findings in Thai patients conflict with those of a study in the USA that found less reduction in PAS area, while one in Turkey found approximately twice the reduction in PAS area as a percentage (Greco et al., 1990, Guven and Saracoglu, 2005). This suggests that the effect of mandibular setback may be ethnicity-dependent. However, another Turkish study where the setback amount was approximately 50% more than ours found a similar reduction in PAS area (Tselnik and Pogrel, 2000). This suggests that the findings of a study may also be affected by the specific patients evaluated, because since mandibular setback is an elective, often cosmetic, surgery, it is difficult to standardize setback amounts between studies. Indeed, studies in Japan reporting setback amounts ranging from 5.95-9.1 mm did not demonstrate a setback amount-dependent reduction in PAS width (Gu et al., 2000, Kawakami et al., 2005, Muto et al., 2008, Abdelrahman et al., 2011).

Lateral cephalograms are commonly used to evaluate the locations of craniofacial structures before and after mandibular setback surgery. Previous studies measured the PAS from cephalograms in distance (Hochban et al., 1996, Eggensperger et al., 2005, Kawakami et al., 2005, Chen et al., 2007, Cho et al., 2015, On et al., 2015), angles (Hochban et al., 1996), and area (Tselnik and Pogrel, 2000, Guven and Saracoglu, 2005). The hard tissue reference points that are used in measuring the PAS area are reproducible and easily defined (On et al., 2015). However, some soft tissue reference points are movable and uncontrollable such that they cannot represent the same position in every cephalogram. Head and neck posture and tongue position during imaging also varies, which can affect result interpretation. However, there have been some studies in which PAS was measured in area using soft tissue references points where PAS area was significantly decreased (Greco et al., 1990, Enacar et al., 1994, Tselnik and Pogrel, 2000). Although using cone beam computed tomography (CBCT) imaging can determine exact in vivo volume change, measuring airway dimensions using lateral cephalograms has been shown to correlate with CBCT measurements (Riley et al., 1987). However, although CBCT currently plays an important role in dentistry because of its three dimensional measurements, it is not routinely used to evaluate the PAS before and after the surgery.

Measurement accuracy depends on the use of area boundaries that are easily defined as performed in this study. The bony reference line (the palatal plane) is not difficult to draw between ANS and PNS and is not changed by BSSRO surgery. The soft tissue outlines we used are clear on lateral cephalograms and have been used in previous studies (Tselnik and Pogrel, 2000, Guven and Saracoglu, 2005) for measuring PAS area. However, the PAS area evaluated in the present study represented only the oropharyngeal airway, because the nasopharyngeal airway should not be changed by BSSRO surgery. Therefore, the superior border was defined at the lower part of the uvula and parallel to the palatal plane.

Numerous retrospective studies (Hochban et al., 1996, Tselnik and Pogrel, 2000, Cho et al., 2015), including ours, have found statistically significant reductions in PAS following BSSRO, however, it is important to recognize that statistical significance does not equate with clinical significance. Indeed, two systematic reviews and one umbrella review (a review of systematic reviews) on the development of OSA following mandibular setback surgery found scant evidence that mandibular set back results in OSA (Fernandez-Ferrer et al., 2015, Canellas et al., 2016, Tan et al., 2017). The lack of development of OSA despite the reduction in PAS following mandibular setback surgery may be because in Class III malocclusion patients, the PAS is larger than that in Class I individuals (Muto et al., 2008, Castro-Silva et al., 2015). Moreover, adaptive postural changes may prevent OSA (Muto et al., 2008).

A limitation of most previous studies concerning the effect of mandibular setback surgery is that they were retrospective, used 2D lateral cephalograms to determine PAS changes, and did not perform follow-up evaluations of more than 1 year. In the future, prospective clinical studies using 3D imaging such as CBCT and longer-term follow-up should be performed.

Conclusions

In the present study, there was a significant correlation between the amount of setback and reduced PAS area at six months follow-up after surgery. Moreover, the PAS area gradually decreased over time from the post-operative value to that observed at the one-year follow-up. Therefore, the surgeon should be aware of the risk of pharyngeal airway reduction in patients who undergo mandibular setback surgery.

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